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Understanding the residential customer perspective to emerging electricity technologies

Informing the CSIRO Future Grid Forum

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Executive summary

Australia's energy sector has entered a period of unprecedented transformation and expansion. It is estimated a A$240 billion investment will be required in the gas and electricity sectors over the next 20 years to meet generation, transmission and distribution requirements (Department of Energy Resources and Tourism, 2012). The willingness of the residential customer to accept and adopt the suite of technologies a future electricity grid is likely to comprise has strong potential to influence whether it can achieve the potential it purports; namely a system that is reliable, sustainable, personalised, affordable and resilient. Research in the field of technology uptake has shown there is much more to the adoption of a technology (which includes 'non-hardware' solutions to problems such as policies and initiatives to influence customer behaviour) than its perceived usefulness (Niemeyer & Littleboy, 2006). To help make sense of this complexity it is necessary to understand what factors may lead to a change in acceptance and adoption, and why.

Social psychology research has shown current attitudes and knowledge of residential customers can either enable technology acceptance and uptake, or act as a barrier (Stern, 1992). Thus, current attitudes are an important influence on the trajectory a technology will take. While research indicates attitudes vary in the degree in which they are persistent over time and resistant to change, under certain conditions attitudes are influential in how an individual processes information and (albeit with less consistency) influential in predicting behaviour. The attitudes of today do not predict what attitudes, knowledge or behaviour might be in the future. Understanding the current attitudes and knowledge of residential customers does however provide important insight for how residential customers might react to information presented to them, what features of a technology encourage acceptance and what conditions inspire behaviour change.

This report has been prepared for the Future Grid Forum and aims to contribute a social dimension to their consideration of current and potential issues and opportunities facing the electricity system. As well, this report provides an evidence base for the development of their response strategies. A desktop study has been undertaken to review the results of a range of studies, both in Australia and overseas, exploring knowledge and attitudes towards emerging electricity technologies to determine the overall acceptability from a residential customers' perspective. It also draws on theories from psychology and social science to present valuable insight into which features a residential customer is likely to accept, those that may require strategies for improved adoption, and those that may require modification. Results from the range of research studies reviewed have highlighted a number of key issues relevant to the residential customer and the future of Australia's electricity grid.

Firstly, electricity use to date has been 'invisible' to the residential customer, resulting in a lack of awareness, knowledge and incentive to participate. Evidence suggests household knowledge of energy use is low; particularly in terms of which appliances contribute most to bills (AECOM, 2011; Deloitte, 2012). Many of the technologies proposed for the future electricity grid require residential customers to be much more aware and involved in their energy consumption, and in some cases, production. While household knowledge and awareness of a number of new and emerging electricity technologies is also low, in most cases, it shows residential customers are willing to investigate and even try technologies and initiatives once the concepts are explained in detail (Department of Climate Change and Energy Efficiency (DCCEE), 2011; Smart Grid Consumer Collaborative (SGCC), 2013; Smart Grid Smart City, 2012). There are some reports to suggest some residential customers are already expressing interest in becoming more aware and taking control over how they consume and produce their electricity. While many emerging electricity technologies (i.e. smart meters, flexible pricing, and direct load control) have received mixed reactions, initial negative reactions are often overcome once knowledge of the technology increases and key concerns (i.e. health and privacy concerns for smart meters; impact of flexible pricing on vulnerable households) are addressed. There are reports which suggest there is scepticism amongst residential customers that the proposed benefits will be realised and key concerns will be adequately addressed.

Secondly, while many residential customers say they are willing to change their behaviour (i.e. to reduce their energy bills) they continue to behave in ways that are contradictory to their intent (i.e. increase use of energy intensive appliances). Research suggests that motivations (i.e. to help the environment) do not necessarily translate into behaviour (i.e. turning off lights, installing solar panels); other factors come into play (social norms; the extent to which the person believes it is easy or difficult to take action). Renewable energy is an example of this. While uptake of 'green power' in Australia has experienced growth in recent years, uptake of 'green power' products was initially very slow. Lack of strong social norms and personal relevance, inconvenience of switching, uncertainty about the quality of green electricity and lack of accurate information were identified as barriers to the uptake of green power.

This issue is not unique to renewable energy. Many residential customers say they are willing to pay a price premium for various emerging technologies, but only a small number make the leap from interest to purchase/premium payment. There are reports to suggest residential customers are generally not willing to pay more than the expected value of return for these technologies. Cost has been shown to be top of mind and therefore is acting as both a primary motivator and a key barrier for uptake. As an example, higher electricity prices have been shown to encourage peak load reduction but the high price of an electric vehicle compared to the alternative is a current barrier to its widespread adoption. While cost is most commonly the predominant factor, studies do suggest there are other complementary decision factors that residential customers consider, including reliability, quality, safety, control and environment. There are, however, instances where these factors can be more influential than cost. As an example, early adopters of a technology often rate other features as more important than cost. Similarly, economic incentives were found to not always be a motivator for the uptake of distributed generation technologies; rather features such as environment and control were more highly regarded by some. Likewise, it has been shown that early adopters of electric vehicles do so more for ideological reasons than any cost benefit. Research has shown that technologies that appeal to early adopters and gain a strong following amongst these customers may struggle to find mass acceptance or take some time to transition from niche to mass-market appeal. For widespread adoption, it is likely cost will be an important factor.

It is important to note that evidence suggests a socio-economic profile of an individual is not a consistent predictor of attitudes, values and beliefs, but it may be an indicator of their capacity to take action. For example, low income customers consider the environment and energy efficiency as important as the general population, but their capacity to take the necessary action may be limited by their circumstances. That is, a low income earner is just a likely to have positive attitudes towards an electric vehicle as a high income earner, but the cost of the technology is a barrier for them to purchase one. The same example could be used for distributed energy technologies such as solar photovoltaic's (PV). There are also reports showing vulnerable households do not perceive certain behaviour changes (i.e. to shift peak load) any more difficult than the general population.

Such findings are applicable to the debate around the impact emerging electricity technologies, such as flexible pricing, has on vulnerable households. Recent modelling suggests, given certain conditions, most residential customers can benefit from flexible pricing, including vulnerable households. There are however reports to show low income customers often have less awareness and knowledge about emerging technologies and initiatives than the general population and show different communication preferences and behaviours. A thorough understanding of the impacts these technologies have on vulnerable households, and the implementation of necessary measures to avoid any negative impacts, is necessary to ensure the future electricity system is an equitable one.

Finally, results from research suggest, while residential customers need information to assist them in decision-making, the quality of information matters. Information and feedback needs to be clear, accessible, appealing, relevant and timely. Key components of successful implementation programs included customer involvement through engagement, education, consumption feedback and supporting technology. One vital component of effective engagement is trust and often utilities do not currently command much public trust. Trust can evolve over time and there are reports that indicate residential customers have expressed an interest in forming a mutually beneficial 'partnership' with their utility company. It is clear that the relationship between the residential customer and the electricity sector will be fundamental moving into the future.

Based on the findings of this desktop study the following conclusions are drawn:

- Most residential customers have low knowledge (and experience) of many of the emerging electricity technologies and of their energy use, particularly the contribution of appliances to electricity consumption costs.
- Additional effort will be required by the electricity sector and government stakeholders to ensure vulnerable customers are provided with the necessary information to ensure they too are able to make informed decisions.
- In many cases, attitudes of residential customers are not yet strongly formed about many emerging electricity technologies, presenting an opportunity for early engagement.
- Reducing the uncertainty that surrounds emerging electricity technologies is paramount. To date concerns are predominately around impacts on privacy, health and vulnerable households.
- Building trusting and respectful relationships between the residential customers, the electricity sector and government stakeholders, will be imperative for the future of Australia's electricity sector.
- To help build trust, engagement with customers should start early; it should be ongoing rather than a one-off activity, include trusted organisations (e.g. community and consumer groups and local councils) as well as the electricity sector and involve two-way communication.
- How attitudes and knowledge are acknowledged and addressed today (or not) will influence the uptake trajectory of the technology into the future.

Key findings

Smart Grids and Smart Meters

- Smart grid technologies have received mixed reactions from residential customers.
- Residential customers lack awareness and sufficient information to make informed choices related to smart grids, but attitudes are generally positive after receiving information about the proposed benefits.
- Positive impressions revolve around increased reliability and ease of connecting renewables to the grid, and to a lesser degree greenhouse gas emission; unfavourable opinions were data privacy and health concerns.
- Both positive and negative opinions are expressed around either a gain or loss of control of energy usage to the utility.
- Cost impact is still top of mind, but there are other, complementary decision factors that customers consider.
- Low income customers tend to have less awareness and knowledge about smart grids and smart meters than the general population and different communication preferences and behaviours.

Direct load control

- Trials have successfully demonstrated reduced energy consumption through direct load control.
- How the technology is communicated to residential customers can influence how the technology is perceived. Presenting information about the society wide benefits of DLC has been well received in trials to date.
- The key barriers to uptake have been identified as residential customer perceptions regarding capability of the technology and its compatibility with appliances, as well as liability issues with respect to potential equipment damage. It also has the potential to be seen as an invasion of privacy, even at low level or for short periods of time.
- Necessary customer protection is an important consideration for DLC (and other smart grid technologies).

Flexible pricing

- Some pricing programs have been shown to be more successful than others, both in terms of demand reduction results and acceptance by the customer.
- Both positive and negative public responses have been received for the various pricing programs, but there seems to be a general willingness by residential customers to investigate and even try flexible pricing once the concepts are explained in detail, along with the reasons for the price incentives.
- Residential customers need more information to assist them when considering flexible pricing offers.
- The impact of flexible pricing on vulnerable households is a key concern but recent modelling suggests most customers can benefit from flexible pricing, including vulnerable households.
- Necessary measures must be implemented to ensure any negative customer impacts are minimised.

Real-time feedback

- Large-scale conservation effect from feedback is more likely in the range of 3–5 percent, not 6-10 percent as previously estimated.
- The quality of information provided is influential. Information needs to be clear, accessible, appealing, relevant and timely.

Vehicle-to-grid (V2G)

- Purchase decisions for early adopters of electric vehicles are likely to be for ideological reasons.
- Reduced air and noise pollution, reduced carbon emissions and less reliance on oil are benefits valued by residential customers.
- Early adopters of electric vehicles are likely to be well educated, child-free with strong environmental values.
- Cost is a barrier to widespread uptake of electric vehicles, as is lack of charging infrastructure and poor driving distance.

Energy efficiency

- Household knowledge of energy use is low; particularly in terms of which appliances contribute most to bills.
- Residential customers say they are willing to change their behaviour to reduce their energy bills; yet continue to increase use of energy intensive appliances.
- Low income customers consider the environment and energy efficiency as important as the general population but less able to take action.

Distributed generation

- The public is generally willing to consider distributed generation technologies.
- Distributed generation will be attractive to individuals who care about the environment; particularly those with more positive attitudes and subjective norms towards reducing household energy consumption, and those who rate the importance of climate change high.
- Reliability and durability, safety levels and the reduction of household emissions were judged as most important features of distributed generation technologies; whereas, ease of use and ease of installation were judged as least important.
- Self-sufficiency and energy-independence were also rated as positive features.
- Pro-environmental behaviour, knowledge of energy and the environment, and values are not predictors of acceptance nor are income, age or electricity consumption.
- Economic incentives are not always a motivator for adoption of distributed generation.

Solar PV

- Solar PV is generally well accepted by the public.
- In deciding to invest solar PV, householders' value cost savings, reliability and durability of the technology and meeting electricity needs as the most important attributes.
- Residential customers are not particularly concerned with aesthetics, but they do want the system to be efficient, durable and practical.
- Good impact on the environment has also been shown as a motivating factor to acquire PV systems.

Renewable energy

- Attitudes toward renewable energy are generally favourable.
- While many people are in support of renewable energy, large scale operations may still meet some public opposition.
- While many customers are supportive and say they are willing to pay a price premium, only a small segment move from interest to purchase of 'green power'.
- Lack of strong social norms and personal relevance, inconvenience of switching, uncertainty about the quality of green electricity and lack of accurate information have been identified as barriers to the uptake of 'green power'.
- How a technology is presented to a customer may impact whether it is adopted (i.e. voluntary vs. mandatory; user pays vs. everyone pays).

Customer motivations

- Cost is the primary motivator for the residential customer and also a key barrier to adoption.
- Residential customers want to save as much as possible, and are not willing to pay more than the expected value of return.
- Reliability and quality service were common expectations of residential customers for their electricity utility.
- Residential customers increasingly desire more control of energy usage, and in some instances generating their own power.
- Energy use is determined by socio-demographic variables, whereas changes in energy use appear to be related to psychological variables.
- Socio-economic profiles of individuals indicate their capacity for action, but are not always a consistent predictor of environmental concern.
- Motivations to help the environment do not necessarily translate into environmental behaviours.

Level of engagement

- To date, electricity use has been 'invisible' to the residential customer, resulting in a lack of awareness, knowledge and incentive to participate.
- If new technologies and initiatives are to be successful people need motivation and knowledge necessary to adopt them.
- Residential customers are genuinely interested in forming a mutually beneficial 'partnership' with their utility company to control their consumption and help the company achieve its objectives
- Key components of successful programs included customer involvement through engagement, education, consumption feedback and supporting technology.
- Effective engagement requires trust. Utilities do not currently command much public trust.

1 Introduction

1.1 CSIRO Future Grid Forum

Australia's electricity sector is expected to undergo a major transformation over the coming decades (Australian Energy Market Commission (AEMC), 2013; Department of Energy Resources and Tourism, 2012). This transformation includes the replacement of ageing infrastructure, the integration of new cleaner generation and smart energy management technologies, and a greater customer influence on market outcomes (Department of Energy Resources and Tourism, 2012). The transformation will cover all aspects of the energy chain and the associated investment in the domestic electricity and gas system could exceed $240 billion by 2030 (Department of Energy Resources and Tourism, 2012).

In preparation, CSIRO is facilitating Australia's first, whole-of-system Future Grid Forum to evaluate all major options for Australia's future electricity system that will shape Australia's future electricity supply, prices, and the industry's carbon emissions. Over 35 industry partners are working together in the Forum to explore a future vision for Australia's electricity system. Industry partners include electricity generators, distributors, transmission service providers, retailers, regulators, state and federal government, customer and environment groups.

As a way of stimulating Forum participants' thinking about the challenges that might lay ahead, the Future Grid Forum undertook a scenario development process. Participants developed four scenarios to explore the possible future boundaries of the electricity system.

Figure 1: CSIRO Future Grid Forum Scenarios

Concepts such as demand management (DM) and distributed generation (DG) feature in these future scenario options. The future of demand management is expected to incorporate the likes of direct load control, flexible pricing, real-time feedback, energy efficiency measures and vehicle-to-grid capability; with many of these elements being reliant on a wider concept of a 'smart grid' and devices such as 'smart meters' and 'smart appliances'. Likewise, distributed generation involves the acceptance and uptake of technologies such as solar PV systems, gas generation and energy storage systems. Additionally, many of the concepts and technologies within DM and DG rely on the customer being actively engaged with their electricity use, and in some instances, production. While the technological development of these features is important, the willingness of customers to a) accept the suite of technologies proposed and b) become more engaged equally influences whether the future electricity system achieves the outcomes desired; namely an electricity system that is reliable, sustainable, personalised, affordable and resilient.

1.2 Scope and objectives of this study

The purpose of the desktop study is to inform the Future Grid Forum about how residential customers might influence the future development of the electricity network and its associated products and services. In particular, this report provides insight into:

- Current trends and attitudes
- Customer awareness and knowledge
- Willingness for change
- Information needed to change

Some questions of particular interest to the Future Grid Forum include:

- What are the current trends and attitudes to the range of issues/topics relevant to the FGF?
- What information does society need to make informed decisions/change behaviours?
    - Do they feel like they know enough already?
    - If not, how/when and from whom would they like to learn more?
- What portion of the public wants to change the way they interact with their power supply? (including demand management processes like giving over control of their air conditioning)
- What is the current level of understanding of what is the biggest power using appliance(s) in the home?
    - Does this affect their choices?
    - For example, are they aware what important loads they might have the opportunity to shift around during the day?
- What gaps exist in research?

This desktop study reviews the results of a range of studies, both in Australia and overseas, exploring residential end-user knowledge and attitudes towards emerging technologies to determine the overall acceptability from a residential customer perspective. It also draws on theories from psychology and social science to present valuable insight into which features a residential customer is likely to accept, those that may require strategies for improved adoption, and those that may require modification.

To maintain a manageable scope, the focus for this study is to understand how residential customers might influence the future development of the electricity network. The focus therefore is on an individual household level and the technologies that will have a direct effect on individual lives. It is however important to acknowledge that a social context extends past thinking about the residential consumer. While certainly an important component, there are decisions beyond the household that society will also influence. Motivations of individuals differ depending on whether they are making decisions based on the impact to themselves (as a consumer) or to society at large (as a citizen) (Niemeyer & Littleboy, 2006).

The future of Australia's electricity grid will involve decisions as both an individual consumer and as a citizen. 'Community energy' for example will be considered differently, as will the infrastructure side of electricity grids. The acceptance of above ground high voltage lines is one relevant example (M. Cotton & Devine-Wright, 2012). The aim of this report is however to provide an evidence base to support Forum discussions and the key recommendations in the final report, thus the technologies reviewed in this report are closely aligned to those referred to in the scenarios developed.

It is also important to acknowledge some of the challenges and limitations of the research reviewed. Much of the research tended to rely heavily on survey methods to determine attitudes and knowledge towards a technology. This can be problematic when technologies are emerging, as knowledge is often low, so a survey of attitudes at this point is limited to uninformed opinions. Similarly, where technologies are emerging, some areas have been more extensively researched than others. Additionally, research in this area is ongoing and many research projects and trials are underway and still awaiting results. And while peer-reviewed research was sought, it was not always available. Likewise, it was not always possible to access the details to enable critical evaluation. In some instances, only research summaries were available for review. Finally, sample size often also led to limitations. Sample sizes were often small and therefore not representative of the wider population. With these challenges and limitations recognised however the desktop study provides a useful insight into the residential consumer at this moment in time and the influence they might have on the future of electricity in Australia.

2 Current attitudes and knowledge

The term ‘technology’ incorporates a wide array of processes, devices, practices and products (Grübler, Nakicenovic, & Victor, 1999), which are usually devised in order to address some definable problem; in the case of this study, a future electricity grid that is affordable, sustainable, reliable and secure. Technologies may include the adoption of ‘hardware’ — goods and materials that embody or produce electricity but also include a wide variety of ‘non-hardware’ solutions to problems such as policies and initiatives to influence customer behaviour that combine knowledge about the operation of social systems; and the organisation of infrastructure, such as transport network (Niemeyer & Littleboy, 2006).

It is generally accepted that technology does not just ‘happen’, but emerges as a result of a relatively complex set of processes whereby different technologies are conceived developed and ultimately adopted as part of social and economic practices (Niemeyer & Littleboy, 2006). There is much more to the uptake of a technology than its perceived usefulness. While perceived usefulness is certainly a factor, social and political factors also come into play. So, when trying to understand the process of technology uptake, social context (political, information systems etc.) is as important as economic imperative. Not only is the social context transformed by technology; the social context provides the very backdrop of technology uptake (Niemeyer & Littleboy, 2006).

While the need to understand the social context is compelling, the resulting picture is complex. Being too generalised neglects important processes, but because interaction among even just a few basic social variables can produce unanticipated results, trying to account for too much is also error prone (e.g. Baxter, Eyles, & Elliott, 1999). To add to this complexity, the dynamics that explain uptake at one point in time may no longer explain events at different times in the future. This often raises the question, if there is potential for the dynamics to change in the face of technological progress, should decisions be made on the basis of existing or future attitudes? To help make sense of this complexity, it is necessary to understand what factors may lead to a change and importantly, why (Niemeyer & Littleboy, 2006).

Expressing an attitude involves making a decision about liking or disliking, or favouring or disfavouring a particular issue, object or person. Attitudes are learned, rather than an innate response, and may occur through direct experience, vicariously through interactions with others, or be a product of cognitive processes (i.e. obtaining and storing knowledge). Attitudes vary in the degree in which they are persistent over time, resistant to change, influential in guiding information processing and influential in predicting behaviour (Maio & Haddock, 2010). Attitudes which are felt strongly are more likely to be stable and enduring, whilst weak attitudes are more flexible and likely to be constructed on the spot (Maio & Haddock, 2010). Attitude strength can be influenced by a range of (and often more than one) factors including (but not limited to): the ability to recall the attitude from memory, whether or not a person has had direct experience with the issue/object, how important a person rates it in relation to other things, and whether or not a person has mixed feelings about it. Finally, attitudes influence the type of information people seek and/or take notice of and how information is interpreted. How a person feels about information provided for example can be biased in the direction of an individual’s attitude (Vaughan & Hogg, 2002). Current attitudes and knowledge of residential customers can either enable or act as a barrier to technology acceptance and uptake and thus are an important influence on the trajectory a technology will take.

This section of the report explores the current attitudes and knowledge of the technologies that the Future Grid Forum has referenced in their future scenarios. As outlined above, the future scenarios assume the introduction of various demand management strategies, varying input from distributed energy sources and an increased contribution from renewable energy sources. Many of these technologies are reliant on the wider concept of a ‘smart grid’ and the associated ‘smart meter’ and as such, attitudes towards and knowledge of the ‘smart grid’ and ‘smart meter’ are discussed in the first instance.

2.1 Smart Grids and Smart Meters

Existing electricity meters installed in Australian households are accumulation meters that record the total consumption of electricity between readings and are unsuitable for readings between relatively short intervals i.e. daily or hourly, which are necessary if utilities want to better understand and respond to demand issues. Governments and utilities throughout the world have begun to invest in the development of smarter electricity grids. The European Technology Platform Smart Grid (ETPSG) defines a smart grid as: *"...an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies*". In 2010, more than US$18 billion was spent on smart grid projects globally (Williamson, 2012; Zpryme Consulting, 2010). One of the first tasks has been to install advanced utility meters, or smart meters, to replace the current analogue accumulation meters (Ehrhardt-Martinez, Laitner, & Donnelly, 2011).

A smart meter is an electricity recording device that collects data at discrete intervals and provides that information remotely to the relevant electricity company. Smart meters enable retailers and distributors to offer new tariff structures (such as time-of-use and critical peak pricing) to customers. They also allow retailers or distributors to offer direct load control options. In addition, retailers may choose to provide electricity use data to customers that encourage them to conserve electricity and/or better manage their electricity demand. Smart meters also provide the potential ability for retailers or distributors to improve customer service levels (i.e. improve their responsiveness to problems that occur within the network) (NERA Economic Consulting, 2008). These options are discussed in further detail in subsequent sections of this report.
Most smart grid projects around the world are in their early stages of planning or implementation, but some have advanced far enough along to provide useful insight into the potential benefits. Reports on smart metering and smart grid in Ireland, Australia, and the UK document substantial societal benefits (i.e. cost savings, environmental benefits and lifestyle improvements) but reactions to smart grid technology have been mixed and there are instances around the world where the dissemination of smart grid technologies has achieved less customer uptake than desired (Global Smart Grid Federation (GSGF), 2012; Smart Grid Australia (SGA), 2012).

The Australian Story

In Australia, a number of roll-outs and trials have commenced, focussing on one of the main components of a smart grid, the smart meter. In response to energy shortages in 2006-2007, the Coalition of Australian Governments (COAG) committed to a national smart meter roll-out where "benefits outweighed the costs"(Global Smart Grid Federation (GSGF), 2012). In 2006, the State of Victoria received approval to commence a mandatory roll-out of smart metering infrastructure (with time-of-use pricing). Initially all costs associated with this deployment were passed along to customers, including the cost of the smart meter itself. After negative customer reaction to the project led to a moratorium in March 2010, some subsidies were introduced when the Victorian government announced its continuation in December 2011 (Department of Primary Industries (DPI), 2011). It is now expected that every Victorian household will have a smart grid installed by September 2013, albeit with some customer opposition (Department of Primary Industries (DPI), 2011; Global Smart Grid Federation (GSGF), 2012).

New South Wales (NSW) has also proceeded with a smart meter trial deployment. Two examples include the "Smart Grid, Smart City" trial and the "Intelligent Network Communities" project. As part of the Intelligent Network Communities project, electricity retailer, Essential Energy, is testing advanced metering infrastructure (AMI), certain customer products and education, distributed generation and storage with 4,000 customers in NSW. The project is presently in its implementation stage (Global Smart Grid Federation (GSGF), 2012). The "Smart Grid, Smart City" trial was initiated in Newcastle, NSW (Global Smart Grid Federation (GSGF), 2012) by the Department of Resources, Energy and Tourism (DRET) and AusGrid. Since 2010, up to 30,000 households have participated in the $100 million Smart Grid, Smart City project (Clarke, 2013). The retail business managing the customer engagement in the residential sector in this trial is Energy Australia has been on board since the second half of 2012. The project includes smart sensors, new backend IT systems, smart meters, and a communications network. It is a demonstration project that gathers information about the benefits and costs of different smart grid technologies in an Australian setting. As part of the trial, customers will monitor their energy use and calculate energy costs and greenhouse gas emissions. They will also be enabled with a household energy management system, giving them wireless control of their appliances (Global Smart Grid Federation (GSGF), 2012). The final Monitoring and Measurement Report will be available after September 2013 when the Smart Grid Smart City trial ends. The following findings from the trial to date were shared in the most recent progress update (June 2012):

- Some customers will oppose smart meter installation, regardless of a legislated right to replace a meter and despite attempts to convince customers of the benefits.
- Escalation and opt-out processes are essential and must be explained to those interacting with customers.
- Allowing customers to choose not to have equipment replaced or upgraded may set an awkward precedent for the network operator.
- Reasons for not wanting a smart meter, such as concerns over being moved to a time-of-use (TOU) tariff, fear of electromagnetic interference, temporary power outages etc. should be fully investigated and explanations made available to those addressing customers' concerns.
- More education and awareness of benefits are needed (Smart Grid Smart City, 2012).

Around the same time, in April/May 2012, more than 2,000 residential energy decision makers completed a national online survey, administered by Smart Grid Australia (SGA) to help determine the relative priority of the drivers of their behaviour as it relates to smart grid technologies and energy consumption behaviours. The key findings from this survey show Australian customers lack awareness and sufficient information to make informed energy choices related to smart grids, but are still relatively positive towards the technologies. When participants were asked "Have you heard of smart grids?" the majority (76%) of residential customers answered 'no'. On a 10 point scale more participants (38%) had unfavourable to very unfavourable feelings towards the introduction of smart grid technology than favourable to very favourable (27%), while 33 percent were neutral in their feelings towards the introduction of smart grid technology. Victoria had the least favourable attitudes when asked about smart grids, which is a possible legacy from the negative reactions described earlier, but overall, across Australia attitudes remain relatively neutral (Smart Grid Australia (SGA), 2012). Similarly, when asked to rate their level of agreement on a 10 point scale to the question 'I have enough knowledge about smart grids to make decisions about their benefits for me and my use of energy' almost half (44%) expressed a level of disagreement, 30 percent expressed a level of agreement and 25 percent were neutral. Cost impact was top of mind, but there were other, complementary decision factors that customers consider, which were categorised by SGA as: convenience, control, capability, confidence, cooperation and cachet (Smart Grid Australia (SGA), 2012).

While health and privacy concerns and increased electricity costs have been the main source of concern for customers (Global Smart Grid Federation (GSGF), 2012; Smart Grid Consumer Collaborative (SGCC), 2013), research by Smart Grid Australia has confirmed the concern around privacy is not universally held. They found that some customers will allow access to consumption and personal data if it enables a particular energy efficiency program (Smart Grid Australia (SGA), 2012). A global survey undertaken by Accenture in 2010 of 10,199 residential customers in 18 countries supports this finding. Accenture (2012) report that while data and privacy issues are coming to the fore, some customers are willing to exchange data for information, with more than half of the customers they surveyed stating that third parties having access to their personal information for the purposes of making a program work would not prevent them from signing up for an electricity management program.

International experiences

With so many markets around the world starting their smart meter implementations, the Global Smart Grid Federation (GSGF) (2012) suggests the Canadian experience provides a great benchmark from which to learn, as Canada has already implemented smart meters for millions of customers. Several provinces (Ontario, British Columbia, Saskatchewan, Quebec) have implemented or intend to implement a smart meter rollout. There are also smart grid pilots being conducted in the Provinces of Ontario and Quebec, and other provinces and utilities are undertaking grid modernisation projects which test and incorporate smart grid technologies. Public reactions have been mixed; including in extreme cases protests based on privacy and health concerns (Global Smart Grid Federation (GSGF), 2012). A recent (September 2012) online survey with more than 2,000 Canadians showed 65 percent of respondents have either a complete or a basic understanding of smart meters, and 61 percent have positive attitudes. While awareness of 'smart grids' as a whole concept was low (27%), majority of respondents (68%) still indicated positive attitudes towards 'smart grids' (Smart Grid Canada (SGC), 2012). While many Canadians (71%) felt that smart grids will either save money, or be revenue neutral, 28 percent believed that they will result in higher costs in the long run. Among the perceived downsides of smart grids, 37 percent of Canadians believe smart grids could lead to a loss of control over their energy use (Smart Grid Canada (SGC), 2012).

Canadian awareness levels of smart meters are almost double those in the United States of America (USA). In the USA, the Smart Grid Consumer Collaborative (SGCC) undertook a series of telephone surveys in an attempt to track public awareness, favourability, and understanding of smart grid technology and its customer benefits. The survey was undertaken twice in 2011 (September and November) and once in 2012 (September). Across all three surveys, more than half of the sample (52%, 54%, 52% respectively) had never heard of the term 'smart grid'; and another fifth (24%, 21%, 21%) had heard of the term but said they don't know much about it. Of participants that were 'aware', 52 percent had positive and 26 percent had neutral impressions of smart grid technology. In this survey, attitudes towards smart grid technologies became more positive (from 52% to 70%) after hearing about the potential benefits (Smart Grid Consumer Collaborative (SGCC), 2012a). Positive impressions of smart grid and smart meters revolved around increased reliability and ease of connecting to renewable to the grid whereas unfavourable opinions revolved around loss of control of energy usage to the utility and data privacy concerns.

Similar findings resulted from a survey undertaken by Pricewaterhouse Coopers (PwC) (2012) in the Midwest of the USA. In this survey, 58 percent had not heard of smart grid technology and of those that were aware of the technology, 80 percent did not feel comfortable about their level of knowledge. Participants in this survey identified mutually beneficial goals for smart grids as: increasing the amount of renewable generation sold to customers, reducing the number of outages and promoting faster recovery times, and reducing demand on the grid during peak demand periods. Respondents also perceived a positive impact on greenhouse gas emissions, the cost of electricity, and customer control, but to a lesser degree.

An online survey of over 1,100 residential energy decision makers across the USA in December 2010 showed a gap exists between what customers perceive as important (namely long-term reduction in electricity costs, more accurate meter reads and fewer and shorter power outages) and what they perceive they are likely to receive. Results from this survey also indicate that respondents are not confident that utilities will be able to resolve their key concerns (namely long-term costs/savings, ability to trust the utility, and meter accuracy) in a way that will make them feel comfortable. This indicates there is a lack of customer confidence in the USA that proposed benefits will be realised or that key concerns will be resolved (Lineweber, 2011).

The roll-out of smart meters has also started throughout Europe with new conditions for private households enforced in the directive 2006/32/EC, which requires Member States to introduce, among other things, an instrument or meter that provides feedback on energy consumption and information about energy efficiency. The number of households that are equipped with a smart meter is still very low; as is customer knowledge of smart meters. A study by Forsa on behalf of the Verbraucherzentrale Bundesverband e.V (Federation of German Consumer Organisations, or vzbv) in 2010 analysed the perceptions and evaluations of smart metering in Germany. A survey of 1,000 participants showed knowledge of smart metering is low, with only 3 percent of participants understanding the meaning of the term 'smart meter' (and only slightly more familiar with the German terms "intellingenter" and "neuer" meter). Similar to findings from the USA, after a short explanation of the concept, reactions were positive. Participants saw advantages in having the chance to reduce spending on electricity and exercise a greater control of costs, however they also expressed doubts about the real potential for conserving electricity and saving costs, and major concerns about the necessary investments and possible misuse of data (Paetz, Dütschke, & Fichtner, 2012).

In Switzerland, research undertaken by Kaufmann et al (2012) found that it is important to integrate a solid understanding of customer perceived value of smart metering in order to foster implementation and acceptance of the technology. Researchers in this study suggest a standard offering for the whole market might lead to suboptimal results as it fails to address the heterogeneity in value perceptions and also potential differences in willingness-to-pay. Similar findings are supported by the research undertaken in the USA by the SGCC who found customers are not homogeneous in behaviours, attitudes or opinions towards smart grid technology; identifying five different segments, which they titled “Easy Street”, “DIY & Save”, “Concerned Greens”, “Young America” and “Traditionals”(Smart Grid Consumer Collaborative (SGCC), 2012b).

The Irish customer behaviour trials of over 5,000 participants held over 2009/10 is also one of the largest and most statistically robust smart metering behavioural trials conducted internationally to date. The statistical evidence from this research is that the deployment of TOU tariffs in combination with other demand side management stimuli (i.e. in-home displays) results in reduced energy consumption. Specifically, the residential trial participants achieved reductions in electricity consumption, both overall and at times of peak usage. In this trial 82 percent of participants made some change to the way they use electricity due to the trial, with 74 percent stating major changes were made by their households. More than half (54%) of the participants agreed that the trial also succeeded in making participants more aware of energy usage, with only 18 percent stating there had been no impact on the way their household uses electricity (The Commission for Energy Regulation (CER), 2011).

2.2 Demand management

While Australian households only represent around 25 percent of total energy consumption, they are the biggest contributor to peak demand growth (Australian Energy Market Commission (AEMC), 2013). Despite some success with slowing total energy consumption growth, peak demand continues to rise in some states, increasing pressure to invest in infrastructure to meet these demands (Deloitte, 2012; Mitelman, 2012). Peak demand is forecast to be relatively flat in Tasmania and South Australia in the next decade. However, it will grow 3.2 percent per annum in Queensland and around 1 percent per annum in New South Wales and Victoria from 2012 to 2022, driving the need for investment in network and generation assets. Considerable cost savings can be achieved if peak demand is reduced (Australian Energy Market Operater (AEMO), 2013). Analysis by (Deloitte, 2012) has estimated that the economic value of the peak demand reductions ranges between $1.5 and $4.6 billion, over 2012-2013 to 2021-2022.

Rather than increase infrastructure spending on building spare capacity, it has been proposed to be more economically efficient to manage peak demand by giving customers incentives to consume less electricity at peak times. In-home customer technologies, demand-side management programs and related support services are starting to emerge as a result (Accenture, 2012; Darby, 2013; Deloitte, 2012; Navigant Research, 2012; Owen, 2013). According to Pike Research, in 2012 there were approximately 11 million households globally enrolled in demand response programs. With a compound annual growth rate (CAGR) of 11.6 percent, they estimate that the number of households is due to more than double, to over 23.5 million, by 2018 (Navigant Research, 2012; T&D World Magazine, 2012). Like any technology, demand response programs will be subject to various market drivers and inhibitors that might alter such estimates.

Demand management strategies to be discussed in this report include, direct load control, flexible pricing, real-time feedback, energy efficiency measures targeted at reducing the drivers of peak demand and vehicle to grid (V2G) capability of electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEV).

2.2.1 DIRECT LOAD CONTROL

In direct load control (DLC), the utility has direct control over whether the customer has access to electricity during peak demand. Customers can allow a utility to remotely shut down or vary the usage of selected electrical appliances that use large amounts of energy (e.g. air-conditioners, electric hot water heaters, and swimming pool pumps) because of the two-way communication available with AMI. A DLC programme involves providing economic compensation to customers who are willing to offer electricity-consuming appliances for load reduction at any time of the day. Customer impacts resulting from DLC might arise from the pricing strategy used by the utility, which may include a one-off rebate or incentive payment upon the purchase of an air conditioner with direct load control capabilities, on-going incentive payments to remain in the program or a discount on electricity tariffs for all consumption. Pricing mechanisms such as these are discussed in more detail in the following section of this report. This section will focus on the results achieved by and residential customer attitudes towards DLC.

A number of DLC trials have been undertaken in a number of states across Australia. One of the main most recent trials is the Solar Cities program. The Solar Cities program is a demonstration program designed to promote solar power, smart meters, energy conservation and new approaches to electricity pricing to provide a sustainable energy future in urban locations throughout Australia. Adelaide, Alice Springs, Blacktown, Central Victoria and Townsville were nominated to be the first Solar Cities of Australia. As part of this program, 211 Perth residents have participated in DLC trials. Ten trials were conducted with early results showing an average load reduction of 0.6 kW per participant. Early analysis of 100 people has shown an average consumption reduction of 3.14 percent in their first year since the assessment, while the control group increased their consumption by almost 9 percent in the same period (Department of Climate Change and Energy Efficiency (DCCEE), 2011). In the Blacktown Solar City trial, an air conditioner remote cycling trial resulted in savings of daily energy consumption on hot days of over 29 percent for trial participants, while keeping interior comfort at manageable levels. Also in the Blacktown Solar City trial, participants were encouraged to only use pool pumps early in the morning and/or at night. This has helped reduce peak demand by over 20 percent. The trials have also led to the development of a new product – the "thermaswitch pool timer" (Department of Climate Change and Energy Efficiency (DCCEE), 2011).

Another set of trials specific to DLC have been taken in South Australia since 2006. ETSA Utilities (now named SA Power Networks) have undertaken a range of trials involving domestic customers to determine whether DLC technology is viable as a demand management strategy for Australian network businesses. Phase 1 included 20 domestic sites in the Adelaide metropolitan area, phase 2 had 4,000 residential and commercial sites in the suburb of Glenelg, and phase 3 included 1,000 domestic customers and the majority of the sites were in the new northern Adelaide suburb of Mawson Lakes. In addition to proving some of the technical sides of DLC, it also identified a number of important considerations for the social dimensions of the technology. As an example, Phase II of the trial detected a change in community attitude. Evidenced both by the response within the trial footprint and positive media, ETSA found the community had become open to new ways of thinking about power and how to manage peak demand (ETSA Utilities, 2010). In terms of engagement and communication, results from these trials also suggest the community valued direct and simple communication that avoided technical, market and political emphasis and was prepared to respond with a strong ethos of contribution and involvement in “doing their bit” as long as they understood where the value lay in their contribution. The “every little bit helps” message was one the community felt comfortable with. These initial trials were completed in 2010 and have since led to the launch of a Phase IV Trial and another 8 additional projects which is currently underway. While results are not available from this trial, an important finding to note is, while recruitment success varied between suburbs and regions, ETSA have been able to retain many participants over the course of 7 years of trials (ETSA Utilities, 2012).

Earlier in 2007, sixteen customer focus groups (7-8 respondents each) involving residential customers in both urban and rural areas in South Australia (SA), Victoria (VIC), New South Wales (NSW), Queensland (QLD), Tasmania (TAS) and Western Australia (WA) were undertaken to explore attitudes to DLC. In this study, participants were much more willing to consider DLC when compared to other pricing alternatives (time-of-use and critical peak pricing options). This was generally consistent across all jurisdictions, between urban and regional centres and across different income groups. In particular, participants in Adelaide, QLD, Sydney and Perth and high income earners more broadly expressed the greatest interest (NERA Economic Consulting, 2008). Some concern was expressed regarding the capability of the technology and its compatibility with appliances, as well as liability issues with respect to potential equipment damage.

These concerns were perceived to be the biggest barrier in NSW and VIC for a household considering the offer overall (NERA Economic Consulting, 2008). These findings are in addition to findings in focus groups conducted in the UK in 2009, where external control was quite controversial and seen as an invasion of privacy, even at low level or for short periods of time (Downing, 2009).

A report by the St Vincent De Paul Society (2010) cautioned that customer protection measures are an important consideration for DLC and other smart grid technologies. The report states "It is important that customers are protected from misleading and predatory marketing practices in order for a competitive energy market to work. As customers have limited experience and understanding of DLC contracts, it is crucial that the marketing provisions allow them the right to assess the offer in a timely manner and that they have the ability to change their mind if they find the offer unsuitable." (Johnston, 2010). It is therefore important that concerns regarding customer protection for DLC and other smart grid technologies are adequately addressed.

2.2.2 FLEXIBLE PRICING

Improvements in metering technology has also facilitated the expansion of certain forms of 'flexible pricing' mechanisms by making it cheaper and easier to implement (Flaim, Neenan, & Robinson, 2013; Hemphill & Neenan, 2008). There are a number of different types of 'flexible pricing' mechanisms including, real-time prices (RTP), time-of-use rates (TOU), critical peak pricing (CPP) and peak-time rebates (PTR) (A Faruqui & Lessem, 2012). Table 1 below provides a description of each pricing mechanism.

Pricing Mechanism	Description
Real-time pricing (RTP)	• Charge at a rate that is linked to the hourly market price for electricity. • Customers are typically made aware of the hourly prices on either a day-ahead or hour-ahead basis. T • Prices accurately reflect the cost of producing electricity during each hour of the day, and thus provide the best price signals to customers, giving them the incentive to reduce consumption at the most expensive times (A Faruqui & Palmer, 2012).
Time-of-use (TOU) pricing	• Prices vary according to the time of use within a day (i.e. peak and off-peak tariffs, or peak/shoulder/off-peak tariffs). • The length of the period that is defined as peak or off-peak can vary between jurisdictions according to the characteristics of network load peaks or wholesale cost peaks during a day within each jurisdiction. • By charging TOU tariffs, a customer is given a price signal to change the pattern of electricity use during a day (NERA Economic Consulting, 2008).
Critical peak pricing (CPP)	• A retailer or distributor can charge a higher (on average 3-7 times more than the peak TOU tariff) electricity price for a set number of critical peak events each year. • Sufficient notice (2-24 hours) of a critical peak price period and usually requires communicating that information to customers via short message service (SMS), email, telephone messaging systems or an in-home display (IHD). • As with the TOU tariffs, CPP is a market signal to customers to change the pattern or level of demand and can deliver significant capital infrastructure cost savings and/or retailer hedging cost savings over time (NERA Economic Consulting, 2008).
Peak-time rebate (PTR)	• Instead of charging a higher rate during peak events, participants are paid for load reductions (estimated relative to a forecast of what the customer otherwise would have consumed). • If customers do not want to participate, they buy through at the existing rate. • There is no rate discount during non-event hours times (A Faruqui & Palmer, 2012).

Table 1: Description of the range of potential pricing mechanisms

Numerous analyses have been carried out on customers' sensitivity to price fluctuations when introduced to TOU, CPP and RTP (A Faruqui & Mitarotonda, 2012; A Faruqui & Palmer, 2012; NERA Economic Consulting, 2008). A recent review with 74 observations from around the world, Faruqui & Palmer (2012) confirmed that residential customers are sensitive to price increases; particularly when pricing strategies were paired with AMI. Data from international trials suggest that pricing programs are capable of reducing residential peak demand by up to 25 percent and greenhouse gas emissions by up to 15 percent (NERA Economic Consulting, 2008; Strengers, 2010). As a result many countries, including Australia, have already introduced or intend to introduce some form of pricing mechanism meant to induce behavioural changes to manage demand of electricity more efficiently (Global Smart Grid Federation (GSGF), 2012). In Australia, the State of Victoria intends to move to more widespread adoption of TOU pricing from July 2013 and the Australian Energy Market Commission (AEMC) 'Power of Choice' report suggests TOU pricing should be adopted in the future for network charges (Australian Energy Market Commission (AEMC), 2013; Owen, 2013).

Some pricing programs have been shown to be more successful than others, both in terms of demand reduction results and acceptance by the customer. Flaim et al. (2013) recently undertook a review and synthesis of findings from seven residential field trials completed in the USA and found peak load reductions for TOU are substantially lower (3-10%) than for CPP and PTR (13-22% and 11-22% respectively). Trials conducted in Australia by Energex and Integral Energy found no change in peak demand as a result of the introduction of TOU tariffs only (NERA Economic Consulting, 2008).

In terms of customer acceptance, a 2011 review of 100 pilots from around the world has shown on average 75-90 percent of participants' were satisfied with the pilot that they took part (Stromback, Dromacque, & Yassin, 2011). In a survey undertaken in Australia by Deloitte (2012), there was a general willingness to investigate and even try various pricing mechanisms once the concepts are explained in detail, along with the reasons for the price incentives. Participants in this survey exhibited attitudes ranging from excitement at the potential for them to learn more about their energy use and lower their bills, to defeatist 'there's nothing I can do, prices always seem to go up anyway' views. There was also a belief that the government (rather than energy companies) needs to provide more information on energy use and needs to provide information to assist households in considering flexible pricing offers.

Australian participants in a series of sixteen focus groups in 2008 to explore customer attitudes to different tariff offerings and ways in which customers may modify their behaviour faced with different pricing structures, expressed interest in TOU and noted that it may make them more conscious of their usage and that they could save money without having to change their entire lifestyle. The motivation to adopt TOU tariffs was related to how much money participants thought they may save. Some higher-income respondents thought it may be too much trouble to monitor and so they would not choose to take it up or, if they did, they would be unlikely to change their behaviour. Others (particularly those on low incomes) saw it as a potential way to save on their bills and were prepared to modify their behaviour (e.g., doing the vacuuming, ironing and washing on the weekends). They also commented that they would need to see the proof of savings actually being achieved in order to remain on this form of tariff. Some participants commented that they would be likely to shift their demand, rather than reduce it overall. Participants that were at home during the day were more likely to see TOU tariffs as negative, as they felt they had less scope to modify their behaviour. Overall, the most popular combination for those not at home during the day was TOU tariffs and DLC. Some high income earners saw an opportunity to counteract peak rates during the day with DLC on air conditioning and then benefit from off-peak tariffs in the evenings (NERA Economic Consulting, 2008).

Views on CPP were not as positive with majority of participants in the sixteen focus groups not able to see much benefit to them in adopting CPP. Views included that the need to change behaviour to avoid CPP prices would impact on people's way of life and that only the 'naive' or 'greeny' would do so. Some participants in Adelaide commented that they needed to have air conditioning on hot days. Participants commented that they could leave the house (e.g. go to a shopping centre) in order to avoid CPP events, but that they would have no incentive to adopt this form of tariff in the first place. In this study, a 5 percent discount offered on tariffs at off-peak times was considered to be too low to outweigh the disadvantages and the potential risks of a high electricity bill (NERA Economic Consulting, 2008).

An online survey of over 1,100 residential energy decision makers across the USA in December 2010, found majority of respondents (up to 60%) said the proposed benefits that might result from flexible pricing plans would be important, if they occurred. Fewer than 40 percent of the respondents believe they are likely to experience these benefits (Lineweber, 2011). These findings are similar to those about smart meters, indicating there is a lack of confidence by the residential customer that the benefits purported by utilities will actually be realised.

Key concern: vulnerable households

Research undertaken in the USA showed low income customers are as likely as the general population to participate in TOU or CPR programs (Smart Grid Consumer Collaborative (SGCC), 2012c). Some consumer groups are however concerned flexible pricing programs might penalise vulnerable households with limited capacity or discretion to respond to new consumption data and price signals to limit their energy consumption (Deloitte, 2012; Williamson, 2012). These concerns are based on the fact that lower income customers often rent their homes, cannot readily afford newer, more efficient appliances and may not maintain their existing appliances. Additionally, vulnerable groups such as disabled and senior citizens are at home during peak hours and are less able to shift consumption patterns (Williamson, 2012). Young families, families who have just purchased their first home, low income singles and regional customers not connected to the grid have also recently been identified as new classes of vulnerable customers that are overlooked by most concessions systems in Australia (Deloitte, 2013).

Some trials have experienced negative customer reactions and even resistance to projects incorporating versions of TOU pricing (Global Smart Grid Federation (GSGF), 2012). In Australia for example, community concern about the potential distributional impacts of such pricing mechanisms led to a moratorium on the automatic reassignment of customers onto pricing mechanisms by Victorian electricity distributors (although voluntary TOU pricing has remained available to applicable customers on request). As a result of these concerns, the Energy Supply Association (ESAA) contracted Deloitte to perform a preliminary study into the potential impacts of new pricing arrangements.

The Deloitte study (2012) found that with the introduction of new pricing schemes, electricity costs across a number of customer groups (including vulnerable groups and small businesses) will change. It found the individual effects of pricing schemes are likely to be highly varied and dependant on a wide range of external and inherent factors, in particular the number, age and occupation of household members, the stock of appliances and how they are used and core features of the house, such as insulation or solar panels. Deloitte's modelling estimates that the average change to customer bills will range from a reduction of 4 percent to an increase of 2 percent - assuming customers do not change their pattern of energy consumption. It found that if customers changed their energy consumption in response to flexible pricing, all customer groups, including vulnerable groups, could benefit (Deloitte, 2012). The study also found the largest customer impact will occur between single and dual element customers - with all single element customer groups found to benefit, if they can shift some load. In an earlier study, also undertaken by Deloitte, vulnerable customer groups did not indicate it was any more difficult for them to shift load than the broader non-vulnerable group therefore it was concluded introducing these pricing schemes on a voluntary basis, supported by effective education campaigns that target vulnerable customers in particular will reduce the risk of vulnerable customers finding themselves in greater financial difficulties due to the new pricing structures (Deloitte, 2012).

A more recent report undertaken by St Vincent de Paul (2013) still cautions about the need to measures to ensure customer protection, particularly for vulnerable households stating: “As TOU pricing is set to commence by July 2013, it is important that concession card holders are aware of the value of the off-peak concession for controlled load that does not apply to time based off-peak rates”. This again highlights the importance of adequately address concerns regarding customer protection (Johnson, 2013).

2.2.3 REAL-TIME FEEDBACK

Feedback on energy consumption can be provided indirectly, through measures such as more detailed, frequent and accurate billing, or directly through a web portal, by directly reading the meter, or through a dedicated display device (McKerracher & Torriti, 2013). Over the years, a number of studies have attempted to quantify the effect of varying feedback mechanisms (Abrahamse, Steg, Vlek, & Rothengatter, 2005; Darby, 2006; Ahmad Faruqui, Hledik, & Sergici, 2009; Fischer, 2008; McKerracher & Torriti, 2013; Stromback et al., 2011).

In the Perth Solar City Program, voluntary TOU tariffs were trialled combined with an in-house display, achieving reduced peak periods by an average of 13 percent (Clean Energy Council, 2012). A 2006 report in the UK reviewed the results of a number of studies relating to the effectiveness of feedback on energy consumption. One of the key findings of this review was that studies examining direct feedback through either a meter or a display monitor had observed savings of between 5 to 15 per cent (Darby, 2006). This report cautions against the difficulties in comparing studies, given the considerable differences in sample size (only 3 in one case), duration of study and additional interventions in some cases such as insulation or the provision of financial incentives to save (Darby, 2006). Until recently, the combined literature suggests savings of approximately 6–10 percent. Advances in smart grid technology since this time, have enabled larger sample sizes and more representative sample selection and recruitment methods for display trials. A recent review by McKerracher and Torriti (2013) utilises this new data and argues a more realistic, large-scale conservation effect from feedback is in the range of 3–5 percent.

In addition to calculating possible energy consumption reductions, past studies have analysed what features of energy consumption feedback on have best affect on domestic energy behaviours. Studies suggest that direct forms of feedback and feedback that is provided with greater frequency tend to be more effective (Abrahamse et al., 2005; Darby, 2006). Devices that provide disaggregated or end-use specific, real-time feedback have been described as one of the most innovative and exciting feedback types (Ehrhardt-Martinez et al., 2011). Providing homeowners with real-time feedback on their electricity consumption through a dedicated display device has been shown to reduce consumption but the percentage savings vary widely. Based on a broad sample of experiments and international literature reviews, Energy Research Centre of the Netherlands (ECN) identified the following summary regarding the use of methods and techniques of feedback:

- Time between behaviour and -accuracy of- feedback on resulting energy use and cost is crucial:
- Direct feedback seems to be more effective than indirect feedback (up to 10 percent for indirect feedback, up to 15 percent for direct feedback and up to 20 percent in pre payment programs);
- Feedback seems to be more effective when accompanied with goal setting;
- Historic feedback seems to be more effective than comparative or normative feedback;
- There is more preference for information feedback through an enhanced direct display than through a website (Kester, Burgos, & Parsons, 2011).

2.2.4 ENERGY EFFICIENCY

Improving the energy efficiency of appliances and products has significant economic and environmental benefits for Australia by reducing greenhouse gas emissions and energy demand. It also reduces the running costs of appliances and products for households and businesses. Up until October 2012, the main policy tools used to achieve reductions in energy use from these products were mandatory Minimum Energy Performance Standards (MEPS) and Energy Rating Labels (ERLs), but since this time Australia’s Greenhouse and Energy Minimum Standards (GEMS) legislation has commenced (Equipment Energy Efficiency (E3), n.d). Under the new legislation the Australian GEMS Regulator will replace state regulators in enforcing regulations and creates a national framework by replacing seven overlapping pieces of state legislation (Equipment Energy Efficiency (E3), n.d). This framework aims to provide enhanced monitoring, verification and enforcement and allows the scope of the previous program to be expanded. A range of polices aiming to improve energy efficiency have been implemented across Australia in recent years (D. Cotton & Trück, 2013), but will not be outlined in detail in this report.

While there have been improvements in energy efficiency of many residential buildings and household technologies (refrigerators, furnaces and air-conditioners) over the last 40 years, many efficiency gains have been offset by preferences for larger houses, increased air-conditioning use, and penetration of a greater variety of new appliances and electronics (Ehrhardt-Martinez, Donnelly, & Laitner, 2010). Ehrhardt-Martinez et al. (2010) suggest that unless residential customers are actively engaged in more proactive home energy management activities, efforts to reduce household energy consumption will be severely constrained. Energy efficiency steps available to residential customers range from turning off light when not in need, switching off appliances at the power point, to purchasing more efficient appliances and installing energy saving products such as solar hot water heaters or insulation (Clean Energy Council, 2012).

The Australian Bureau of Statistic (ABS) found in 2011-12 89 percent of Australians took steps to limit their personal use electricity use. Younger Australians (aged 18-24) were less likely to act, with 79 percent taking action compared with 92 percent of those aged between 35-74 years. These figures are supported by a survey conducted by Auspoll and Choice in 2011 that found 95 percent of residential customers were concerned or very concerned about rising electricity prices, and that 89 percent were willing to take action to use less energy (Clean Energy Council, 2012). A report by Pricewaterhouse Coopers (PwC) (2012) also confirms residential customers say they are eager to reduce their energy bills, even if it means they have to change their consumption.

The purchase of high energy consuming appliances is still increasing. Some studies suggest there is a low level of understanding of their household energy use, particularly in terms of which appliances contribute most to their bills (AECOM, 2011; Deloitte, 2012). The ABS found 91 percent of respondents answered yes when asked "Would you be prepared to make changes or take actions to use less energy in your home if you were given more information on how you could do this without compromising your lifestyle"(Australian Bureau of Statistics (ABS), 2012).

Increasing this knowledge has been shown to achieve significant energy savings. An important finding from CSIRO's research with members of the public is the importance of face-to-face communication and knowledge sharing to overcome the gaps in knowledge about the issue and technologies (Ashworth, 2011). In a CSIRO pilot program known as 'Energymark', average household electricity consumption of 172 participants in Newcastle, NSW fell from 14,420 to 9,029 kilowatt hours, with participants managing to cut their power use by 35 percent through the use of energy-saving appliances and the way they used appliances in the home in the first 12 months (Ashworth, 2011). 'Energymark' engage residential customers who are determined to do something to reduce their own personal carbon footprint, to work with CSIRO to convene a group of friends, family, or work colleagues to contemplate the topic of climate and energy over an 8 to 12 month period. Further findings from this engagement process are outlined below in the 'Level of engagement' section of this report. Similarly, in another Solar City initiative in Perth, 3500 residential customers were provided with a 90-minute Home Eco-Consultation. The phone session aimed to inform the customers about what was contributing to their power use and what action they could take to reduce it. On average, households that participated in this program reduced their power use by 12.3 percent (Clean Energy Council, 2011).

Nolan et al. (2008) found that energy saving behaviours was most heavily influenced by social norms, as opposed to concerns for environmental protection, benefits to society, or saving money. This study showed when compared to information that highlighted other reasons to conserve (environment, benefits to society or saving money), it was normative information that created the biggest change in behaviour. Interestingly, the study also showed that respondents did not rate normative information (i.e. reports showing how energy much other people were consuming) as an important influence to their behaviour. These results illustrate the potential power of normative messages for reshaping behaviour despite the fact that their influence is often under-detected by individuals themselves (Nolan et al., 2008).

Ehrhardt-Martinez et al. (2010) suggest the invisibility of energy resources has, in the past, impeded the establishments of social norms i.e. what individuals think others expect them to do, concerning levels of energy consumption. Most energy customers were not only blind to their own level of consumption, but they were equally unaware of their neighbours and other people living in the same city or region consumption. Without an appropriate frame of reference, individual households found it difficult to determine whether their patterns of energy consumption are comparable to similar households. Access to normative information has been acknowledged as a big motivator in modifying energy consumption practices in ways that save money, decrease energy and reduce environmental impacts and is now often provided on utility bills. As discussed in the previous section of this report, the emergence of real-time feedback has potential to improve again on these savings.

An individual's socio-economic profile does not seem to be a determining factor in terms of whether a customer regards energy efficiency as important. In the USA, the Smart Grid Consumer Coalition (SGCC) undertook a survey that suggested energy efficiency was as important to low income customers (88%) as the general population (91%). While there are some statistically significant differences, low income customers' environmental attitudes align fairly closely with those of the general population. Most low income customers (72%) believe that global warming is real, and that saving energy helps the environment (82%), with 80 percent reporting that they try to minimise their impact on the environment through daily actions (Smart Grid Consumer Collaborative (SGCC), 2012b). This study found low income customers to be far less knowledgeable about the actions they can take to make their home more energy efficient (Smart Grid Consumer Collaborative (SGCC), 2012b). This finding is supported by a 2013 report from the Adelaide Solar City Home Energy Assistance Program which found many program participants do not have a basic understanding of their energy use. In particular, there is a lack of understanding on how to use appliances, their running cost and the impact of appliance use on their energy bills (De Bortoli & Murray, 2013). The report highlights that these communities often face additional challenges to understand or manage their energy bills due to language and cultural barriers, unemployment and difficulties in finding suitable housing, and states this lack of knowledge of the relationship between high energy use and the cost of energy is a significant financial risk for low income community groups, particularly new arrivals and refugee communities (De Bortoli & Murray, 2013).

2.2.5 VEHICLE-TO-GRID (V2G) CAPABILITY

Electric Vehicles (EVs) can provide an important component of the smart grid and the benefits that widespread adoption of electric vehicles (EVs) could provide for transport greenhouse gas emission reduction, reduced fuel costs and transport fuel self-sufficiency have been widely documented (Graham & Smart, 2011). EVs also present an opportunity to support intermittent renewable generation with base-load storage (Simpson, 2009). In Australia, the Victorian Government is running a trial to better understand the process, timelines and barriers for transiting to EV technology. The Victorian EV Trial is being delivered by the Department of Transport until mid 2014 and involves 30 vehicles to test the attitude of drivers, particularly in regard to charging behaviour and impressions of overall drivability (Department of Transport, 2012). Applications to be part of this trial were received by 2,200 applicants. Notable demographic features of the applicants included a high proportion with post graduate qualifications, majority living in households with two adults and no children. Additionally, there were a high proportion of early adopters, but most preferred to wait until the benefits of a new product were shown. A substantial number (20%) had already adopted other energy technologies such as solar panels and GreenPower and were environmentally conscious and willing to take action to protect the environment (Department of Transport, 2012).

Respondents held positive attitudes towards EVs and supported government action in this area. This finding of general support for EVs is widely supported (Eggers & Eggers, 2011; Ernst & Young, 2010; Gould & Golob, 1998; Warth, von der Gracht, & Darkow, 2013). Applicants in the Victorian trial agreed that the benefits of EVs include: reduced air and noise pollution, reduced carbon emissions and lessened reliance on oil. They did not agree that EVs would reduce road congestion or the need to travel. Applicants also agreed that EVs could provide local jobs development. Factors which applicants most indicated were barriers to EVs in Victoria included lack of charging infrastructure, cost of new technology and limited driving distance (Department of Transport, 2012).

Research shows consumers are generally not willing to pay an extra premium for EV's (Zhang, Gensler, & Garcia, 2011). However, a study undertaken in the USA suggested that the perceived value of automobiles such as EV's can increase with word of mouth word which in turn leads to a higher willingness to pay (Zhang et al., 2011). The study found price to be the most important attribute for EVs with fuel economy (miles per charge) as secondary and suggested if price and miles per charge are in balance, there is only small niche of consumers who will be interested in EVs. This study therefore concluded for the EVs to reach the mainstream market, the price will have to decrease and miles between charges increase significantly. This has implications if future scenarios are reliant on mainstream adoption of EVs.

An additional risk for the uptake of EVs is if the environmental credentials (i.e. battery disposal) do not meet the expectations of the environmentally conscious customer. Although EVs have zero-emissions at the tailpipe there is considerable discussion about their other environmental impacts. Gould and Golob

(1998) nominate four main issues: (1) comparative impacts with gasoline emissions (2) environmental impact of electrical generation (3) life-cycle emissions and (4) environment and noise. Gould and Golob (1998) do note the last issue is not particularly controversial, since there is general agreement that EVs are quieter than gasoline vehicles.

2.3 Distributed generation

Distributed generation (DG) is another technology based concept that is considered an option that is likely to play an increasing role in the future. In recent years Australia has experienced rapid growth in the use of DG systems. This rapid acceleration has been driven by a range of factors, namely: government subsidies, rapid reductions in capital costs, reductions in solar system installation costs, and a distortion in the way electricity retail prices are structured (ACIL Tasman, 2013). Many of these government subsidies are not likely to be as prevalent in future as they have been in the past, therefore future uptake will be reliant on other drivers (ACIL Tasman, 2013).

The CSIRO Energy Flagship has undertaken a series of studies in an endeavour to understand the drivers and barriers to customer acceptance and uptake of distributed generation technologies. Acceptance of a technology is, in part reflected by its specific features and distributed generation has several features that are relevant to potential customer choices (Gardner, Carr-Cornish, & Ashworth, 2008; Rogers, 1962, 1995). Gardner et al. (2008) identified strong acceptance for distributed generation in a survey of approximately 700 respondents across QLD, NSW, VIC and SA, over May 2007. In this survey, reliability and durability, safety levels and the reduction of household emissions were the features (out of a total of nine features, including cost to install and savings over time) of distributed generation that held the most weight with potential customers. Ease of use and ease of installation were judged as least important.

Again in 2007, eight case studies were conducted in QLD and NSW households that had adopted distributed energy technology (early adopters). Participants were interviewed in depth about their beliefs, attitudes and motivations for adopting these technologies. For most participants, economic factors were a secondary consideration; in fact in some cases, economic incentives had a counterintuitive effect – people delayed installation in anticipation of future rebate increases (Parsons & Ashworth, 2007). Through these case studies, three motivators for adoption were identified: an aspiration of self-sufficiency and energy-independence; demonstrating environmental values; the prospect of catalysing social change (Parsons & Ashworth, 2007). Meanwhile, in a survey undertaken in the same year by the Alternative Technology Association, 76 percent of respondents cited economic incentives as the main motivator required to stimulate further uptake of PV systems (Brandao, 2007).

The research by Gardner et al. (2008) found individuals who care about the environment; particularly those who have positive attitudes to reduced energy consumption and reducing emissions to address climate change, are those most likely to accept distributed generation technologies. Gardner et al. (2008) also found acceptance was higher from males, people with higher education, and those from households with children. Pro-environmental behaviour, knowledge of energy and the environment, and values were not predictors nor were income, age or electricity consumption (Gardner et al., 2008). A separate industry report however suggested the benefits of distributed generation are most likely to be highly valued by customers with the disposable income available to install their own generating infrastructure and knowledge of how to negotiate an effective selling position with supply companies (Williamson, 2012).

Garder and Ashworth (2008) also suggest that when considering the potential uptake of distributed energy technology there needs to be distinction between ‘consumer’ technologies (requiring individual decisions to purchase a particular system) and ‘social’ technologies (requiring collective decisions about the acceptability of a particular course of action) because distributed generation technologies have the potential to be both.

While collectively these findings cannot predict the rate of uptake, they do provide useful insight into how distributed generation technology might be communicated, by focusing on the functions that have the highest utility to the residential customer (Gardner et al., 2008).

2.3.1 SOLAR PHOTOVOLTAIC CELLS

A 2013 report by ACIL Tasman predicts the most likely DG technology to be taken up in the immediate term remains solar PV, and as such is the focus of this report. The report suggests "other technologies such as gas fired micro turbines and fuel cells may become viable in future, but they have not yet 'arrived' in a commercial sense" (ACIL Tasman, 2013). Research shows solar PV systems are generally well accepted by the public. In a series of large group workshops exploring climate change and energy technologies, solar was consistently rated as one of the most preferred energy technologies (Ashworth, Paxton, & Carr-Cornish, 2010). Further details on preferences are outlined in the broader 'Renewable energy' section below.

In 2007, the Alternative Technology Association undertook a survey to explore PV system owners' views and experiences. In this survey, 78 percent of respondents cited 'good impact on the environment' as motivating them to acquire their PV systems (Brandao, 2007). In a CSIRO report on case studies of domestic customers, most participants were not concerned with aesthetics, but appeared to value efficiency, durability, and practicality. In other words, they did not care what the system looked like, but they wanted it to work well (Parsons & Ashworth, 2007).

In 2013, the Australian Solar Institute (ASI) funded the collaborative research project 'Consumer & Utility Interest in Active Participation in the Distributed Energy Market'. As part of this research the Australian Photovoltaic Association (APVA) commissioned CSIRO to design and run a national survey to investigate Australian householders' perceptions of, and willingness to participate in the distributed solar PV energy market. With a total of almost 2,500 participants, six key PV options were examined, including: solar hot water systems, grid connected solar PV systems; grid connected solar PV systems with battery; battery alone systems; off-grid PV solar systems; and community PV systems. The survey results indicate that overall, there is general support by householders to participate in the distributed energy market, particularly through the installation of solar hot water heaters, solar PV systems connected to the grid for energy generation and with battery back-up. The survey data show there is significant evidence of a positive correlation between respondents' support for solar distributed energy technologies and respondents' values, beliefs and norms, which encompass awareness of the impact of energy use and perceived responsibility for associated problems. Households' decisions to install or invest in solar distributed energy systems are determined to a great extent by implicit tradeoffs across a set of technology and service attributes, which are valued differently by individuals. The survey data show that, in deciding to invest in a distributed solar PV technology, householders' value attributes in relation to cost savings, reliability and durability of the technology and meeting electricity needs as the most important attributes. On the other hand, increased safety, ease to install and visual appeal are valued the least important attributes. This ranking of attributes holds across all technology options under consideration. The data analysis presents further evidence that householders' that are more supportive of distributed energy technologies, value environmental benefits more highly than power supply reliability (Romanach, 2013).

2.4 Renewable energy

Increased use of renewable energy sources has increased in Australia and around the world (Bahadori, 2013; Chowdhury & Oo, 2012). A record 13.14 percent of Australia's electricity generation was produced by renewable sources of energy in the 2012 calendar year (Clean Energy Council, 2012), which in 2005 was less than 5 percent (Australian Bureau of Agricultural and Resource Economics (ABARE), 2005). With current policy targets, this is set to double (to at least 20%) before 2020 (Bahadori, 2013; Chowdhury & Oo, 2012; Clean Energy Council, 2011). Globally, attitudes toward renewable energy are generally favourable with a common trend for individuals to express support for renewable energy sources in preference to traditional fossil fuel forms of energy generation and other more controversial technologies (Dowd, Ashworth, Carr-Cornish, & Stenner, 2012).

CSIRO research in Australia has found that the highest level of public support was for solar and wind technologies, followed by other renewable forms of energy. When asked to rank the priority they would give to funding for the deployment of various energy options, participants ranked solar highest, followed by wind, wave/tidal then geothermal (Ashworth, 2011). As part of this research, an online survey (n=1,907) found support for solar PV, solar thermal and wind as an energy source was high with approximately 82 percent of participants agreeing with their use. While coal with or without carbon capture and storage (CCS) technology was 38.8 percent or lower (Hobman & Ashworth, 2011).

In July 2012, the NewDemocracy Foundation convened two groups of 31 participants, drawn randomly from the electoral roll, and selected to be representative of the community, to participate in a citizens jury process in Sydney and regional NSW with a remit to formulate a series of recommendations to the Coalition government about the use of alternative energy sources across the State. Both groups made recommendations to increase the level of renewable energy as a proportion of energy generation, with the Sydney group recommending that 'there needs to be an increased utilisation of renewable energy beyond current Federal targets', while the New England group recommended 'targeted stages to achieve a goal of 100 percent sustainable, renewable' energy by 2050 (Committee., 2012).

While general public and political support for renewable energy is often high, large scale operations frequently raise concerns in local communities, and individual projects often fail because of effective public opposition. Several examples exist, internationally and in Australia, where large scale renewable energy projects have faced public opposition and have stalled or ceased as a result. It is not uncommon to be in favour of community and household micro-generation, yet to be against large-scale utility-owned wind farms (Bell, 2005; Walker & Devine-Wright, 2008). This suggests that while many people are in support of renewable energy, there are still some characteristics of large scale operations that may meet some public opposition. The wind industry for example has recognised this as a potential barrier and has recently released community engagement guidelines and a guide for communities that explains what to expect from a wind farm development (Australian Centre for Corporate Social Responsibility, 2013; Clean Energy Council, 2013).

Similarly, research shows that green energy customers are more environmentally concerned than the general population (Clark, Cochen, & Moore, 2003; Ek, 2005; Hansla, Gamble, Juliusson, & Gärling, 2008), but there are also customers' that are sympathetic to environmental issues that do not necessarily adopt green electricity. Although many residential customers express environmental attitudes and acceptance of renewable energy, only a rather small segment of residential customers make the leap from interest to purchase (Hartmann & Apaolaza-Ibáñez, 2012). This is thought to be due to lack of strong social norms and personal relevance, inconvenience of switching, uncertainty about the quality of green electricity and lack of accurate information (Ozaki, 2011). Figures released by the National GreenPower™ Accreditation Program do show in the 6 years from 2005 to 2011, the number of residential customer purchasing 'greenpower' more than tripled, from 208,086 residential customers in 2005 to 684,601 residential customers in 2011 (Clear Environment Pty Ltd, 2013; URS Australia Pty Ltd, 2006). A published review on the factors behind this growth was not available at the time of this study. An up-to-date evaluation of customer uptake of 'greenpower' in Australia would therefore be a useful contribution to the electricity sector.

On a separate note, it has been suggested that how the option is presented to customer may impact on whether it is adopted. One paper in 2009, suggested that people would prefer their green electricity products to be paid for as a collective contribution rather than as higher bills for individuals who opt for a green tariff (Menges & Traub, 2009). Menges and Traub (2009) suggest this may be interpreted in light of the more general conclusion of political economy that voters prefer an improvement of the environment by means of regulations and prohibitions instead of market-driven activities. Similarly, it could be linked to findings that show inequity aversion to be an important social preference, where inequity averse persons want to achieve an equitable distribution of material resources, not have some having more or less than others (Bolton & Ockenfels, 2000; Fehr & Schmidt, 1999).

3 Preferences and expectations of the modern electricity customer

Changes in the electricity sector have altered the landscape for the residential customer. In the past, there were limited incentives for customers to participate and as a result they showed little interest in engaging in the sector. In the future, the electricity grid will deliver an unprecedented amount of data for use by both the utility and the residential customer. Technologies such as utility advanced meters and in-home feedback devices provide a means by which residential energy customers can become more knowledgeable about their energy consumption practices and become active managers of their energy resource use (Ehrhardt-Martinez et al., 2010). It is important therefore to try and understand how the residential customer might react to these changes, and identify best practice for communication and engagement activities.

Additionally, it is predicted that the introduction of smart grid technologies will bring with it a rising number of 'prosumers' (electricity producing consumers), personalised tariff structures, new energy generation options and energy usage information that is available in real-time. For example, it is likely that decentralised generation from homes and buildings, along with local power plant such as small scale wind farms or district heating systems with combined heat and power plant, will represent very different contexts for energy behaviour in the future. Deployment of such technologies will offer unprecedented opportunities for 'in sight and mind' energy systems and substantially increase the 'visibility' of energy issues in everyday life, making people more aware of how power is generated, supplied and consumed, and closing the current awareness gap between personal energy consumption and the consequences of such consumption for environmental problems such as climate change (Devine-Wright, 2006). It is also envisaged that customers might increasingly expect energy distribution system operators (DSOs) and retailers to do more than keep the lights on, meter energy usage and bill for that usage accurately (Williamson, 2012). It is therefore important for utilities to understand the expectations and motivations of their residential customer. The following section of this report discusses a range of customer motivations and how they influence attitudes and behaviours relevant to the electricity sector.

3.1 Customer priorities and motivations

If new technologies are to be successful, people need motivation and knowledge necessary for adoption (Stern, 1992). A number of studies have been undertaken to try and understand the motivations of residential customers, ranging in scope from motivations for reducing energy consumption, switching energy providers, to adopting a new technology (e.g. (Gardner et al., 2008; Parsons & Ashworth, 2007; Rowlands, Parker, & Scott, 2004). Studies that have investigated residential customers' priorities for their electricity supplier largely come from the USA. Many of these have identified cost, reliability and customer service as being particularly important (Rowlands et al., 2004).

Price of the electricity, quality of customer service, where electricity is generated, environmental effects of the electricity produced by the company, reputation of the company and reliability of electricity supply were rated as the top six priorities of residential electricity purchasers (Rowlands et al., 2004). Similarly, a 2012 survey of the benefits of smart grids found saving money was the highest priority for customers. Other goals, such as understanding daily usage and how it affects their bill, identifying ways to reduce energy usage, and resolving power outages more quickly, were also identified as important (Pricewaterhouse Coopers (PwC), 2012).

Recent findings from the Australian Solar Cities program suggested participants have three clear motivations for taking action on reducing electricity consumption: to save money, to save the environment, and to feel that their actions mean something—that they are part of something greater (De Bortoli &

Murray, 2012). The Adelaide Solar City studies of residential customer behaviour has shown that although most people feel motivated to help the environment, this does not necessarily translate into behaviour change. Although climate change and global warming concerns was important to residents, the main motivator for behavioural change was to save money (De Bortoli & Murray, 2012).

Although price/cost was the primary motivator for the residential customer, it seems it is also the primary barrier to adoption of many technologies. In the EV trial in Victoria, despite respondents reporting they were environmentally conscious and willing to take action to protect the environment, cost remained a barrier to further action (Department of Transport, 2012). Similarly, in a survey about smart grid technologies, results indicate some residential customers are interested, and even excited about smart grid technology, but they generally are not willing to pay much more to reap the benefits. It found customers want to save as much money as possible, and charges for devices and services cannot exceed the expected value of the return. Across the sample, the majority (77%) of customers said they were not willing to pay anything more or pay only up to 5 percent more for such services (Pricewaterhouse Coopers (PwC), 2012). An international study undertaken by Accenture (2012)found 69 percent of respondents indicated they would not be willing to pay a premium for additional products/services (i.e. greater mix of renewable energy sources, improved service priority, multiple billing and payment option, personalised energy reports and tools to help manage usage etc).

Social researchers have explored what factors might help predict the types of people most likely to accept and adopt a technology or encourage behaviour change, generally exploring the link between socio-demographic variables, such as income and education, and psychological variables, such as attitudes and values. Research indicates that household energy use appears to be mainly determined by socio-demographic variables that shape the opportunities and constraints for energy, such as income and household size (Biesiot & Noorman, 1999; Gardner et al., 2008; Gatersleben, 2002). Reducing energy use however, requires making a conscious decision or effort which has been linked to psychological variables, such as attitudes rather than socio-demographic variables. Results from a 2009 study, undertaken in the Netherlands indicate that energy *use* is determined by socio-demographic variables, whereas *changes* in energy use, which may require some form of (cognitive) effort, appear to be related to psychological (Abrahamse & Steg, 2009). An Australian study undertaken in 2008, showed demographic characteristics describe the socio-economic profile of individuals and indicate their capacity for action, but are not always a consistent predictor of environmental concern (Gardner et al., 2008). So while environmental values have been consistently linked to the acceptance of certain energy technologies and positive attitudes towards conservation behaviours, as reported earlier, it is not always associated with behaviour change or adoption (Gardner et al., 2008).

3.2 Level of engagement

Previous research has identified residential customers have little awareness of their energy use, what appliances contribute most to consumption, or the importance of timing in the supply and use of electricity (Darby, 2013). To date, electricity use and its associated network costs has been invisible to the residential customers, leading to a lack of awareness, knowledge and incentive to participate (Darby, 2013; Owen, 2011). Customers, particularly residential customers, are used to playing a minimal role in centralised electricity systems, so a major shift is expected as distributed energy and 'smart grid' concepts emerge, involving two-way communications, and thus some degree of customer participation (Darby, 2013). The changing landscape of the electricity sector, as outlined above, is likely to change the priorities and motivations of residential customers. A question of what level of engagement the residential customer expects or desires is raised as a result. Alongside this is a question regarding the best methods for engaging the residential customer. The following section of the report provides information to help address these questions.

According to a recent survey undertaken in the US (mid-west), residential customers are genuinely interested in forming a mutually beneficial 'partnership' with their utility company to control their consumption and help the company achieve its objectives (Pricewaterhouse Coopers (PwC), 2011). In this study, focus group participants clearly expressed interest in developing a better 'relationship' or ‘partnership’ with their utility company, for the mutual benefit of helping “each other use less energy...meet each other’s needs” (Pricewaterhouse Coopers (PwC), 2011). A separate industry report suggests utilities that make the most of this recent enthusiasm from the residential customer to build relationships, by engaging with them to help understand the what their customers value most are more likely to create better products and a society more engaged and willing to manage their energy demand (Williamson, 2012).

In 2011, global energy think tank, VaasaETT, found that the difference between success and failure is the ability of the program designers to meet customer needs. The VaasaETT global energy think tank questioned the current tendency of the electricity sector to emphasise technological development over and above all other factors, and the comparatively small funding provided to studying the best messages to deliver to customers, their cycles of learning through program layering or the impact of surrounding socio-economic and cultural factors (Stromback et al., 2011).

VaasaETT have also conducted a major global research project to assess the benefits of over 100 demand-response programs, broken down into 460 pilot samples involving over 450,000 households. Based on 22 potential success factors, it found that customer engagement through a combination of technology and information (such as smart meters) was critical to create effective demand responses. Key components of successful programs included customer involvement through engagement, education, consumption feedback and supporting technology (Stromback et al., 2011). This finding was supported, even on a very basic level, when participants in the 2012 SGCC survey were more supportive of smart grid technologies after some additional background information (Smart Grid Consumer Collaborative (SGCC), 2012b). Similar findings were also found in a survey undertaken by PriceWaterhouseCoopers in the same year, with results indicating a more positive view of the technology was received when a written description was provided. With this clearer understanding of the technology’s benefits, nearly 90 percent of survey respondent were at least somewhat to very willing to adopt smart grid technology (Pricewaterhouse Coopers (PwC), 2012).

In a review of customer engagement activities, the International Smart Grid Action Network (ISGAN) suggested a number of requirements for effective engagement. Top of their list was for the need for the influencing organisation to garner trust from its community, suggesting customer attitudes to potential benefits vary according to the level of trust customers have in their electricity supplier (Williamson, 2012). This finding is supported by Niemeyer and Littleboy (2006) who in a literature review of societal uptake of energy technologies found predisposition toward a given technology is dependent on levels of trust in the technology, which may be facilitated by trust in institutions (scientific, industrial and political) involved in the technology process. Several studies have found utilities do not currently command much public trust (Darby, 2013; Downing, 2009; Wilson & Dowlatabadi, 2007). The levels of trust in Australia are suggested to be as low as 54 percent compared to the global average of 68 percent (Accenture, 2010). In a recent (May 2013) study undertaken for the Australian Photovoltaic Association (APVA) trust was highlighted as important and mistrust was commonplace amongst the focus group participants. There was a general mistrust of electricity retailers with participants suggesting they were sceptical about the information provided to them. Across the full sample (n=2,500), respondents trust CSIRO, consumer organisations, scientists or engineers and experts the most to provide honest information. The sources least trusted include the media and electricity and gas companies (Romanach, 2013).

In addition to trust, other characteristics that the ISGAN 2012 Review highlighted as important for effective engagement programs include:

- Extensive pre-planning and review by stakeholders
- Tailored to the target audience
- Simple messages communicated effectively through good choice of themes and mediums
- Community engagement that encourages two way communication as opposed to just raising awareness or selling imposed solutions
- Reduced customer information barriers, and
- Appropriate and appropriately priced products and services to complement the campaign.

Similarly, a review Energy Demand Research Project (EDRP), a trial that ran from 2007 to 2010 exploring the responses of over 50,000 different households in Great Britain in the UK, found that in order to prompt behaviour change, customers need to know what to do i.e. what means should be deployed to save energy and made the following recommendations:

- Quality matters. Information needs to be clear, easily seen amongst other material sent by suppliers (e.g. it may not be effective on a bill) and presented in an attractive way. It also needs to be relevant and timely (e.g. appropriate to the season) and kept up to date.
- Quantity also matters. Regular small pieces of information appear to be more effective than a single delivery of comprehensive information (to provide information in manageable amounts and to maintain behaviour change prompts over an extended period).
- People and households are not all the same. The more closely an intervention can be tailored to particular households or individuals, the more effective it is likely to be.
- Overall, the EDRP shows us that new technology can help us relay consumption information to customers in new and useful ways. However, technology alone is unlikely to achieve engagement and behaviour change without relevant support and information for different types of customers (AECOM, 2011).

Finally, an important finding from research undertaken since 2003 by CSIRO with members of the public is the importance of face-to-face communication and knowledge sharing to overcome the gaps in knowledge about the particular issue and associated technology, rather than one way communication. This research has repeatedly found residential customers are strongly motivated by the idea of being good citizens and often enjoy working in groups of like-minded individuals. They are also looking for leadership and for reliable, objective information from trusted sources such as research organisations (such as CSIRO in Australia) and universities. Trust is a critical element, and having multiple reputable sources from diverse positions, work together to develop advice, can help to overcome competing arguments (Ashworth, 2011).

According to the International Energy Agency (IEA) (2011), one example of a successful customer engagement strategy was ENEL's Telegestore project in Italy. During the rollout of 33 million smart meters, ENEL (Italy's largest power company) dedicated time to educating the public through town hall meetings and dedicated discussions with customer protection groups that had voiced concerns over the collection of data about customer energy habits. While assuaging people's doubts, ENEL was able to explain that most customers' bills could reduce because of smart meters, helping increase customer loyalty (International Energy Agency (IEA), 2011).

The IEA suggests "the demonstration and deployment of new technologies involves some level of risk. The risk must be analysed and addressed jointly by stakeholders...risks can be minimised and projects will be more broadly accepted...risks associated with smart grid development, demonstration and deployment will be lower than the risk of not addressing the coming changes and needed investment in the electricity system" (International Energy Agency (IEA), 2011).

4 Discussion

Many emerging electricity technologies reviewed in this report have received mixed reactions from residential customers. Details specific to each technology outlined above, confirm there are cases around the world, including Australia, where concerns about an emerging electricity technology have impacted on its development. Best demonstrated by the Victorian and other smart meter rollouts around the world, society can delay or halt the implementation of a new technological process if they perceive the risk to be too great (Oskamp, 2000). There is increasing recognition that the public is no longer a passive recipient of technological innovation rather the public's relationship with technologies is influenced by a range of factors that are strong enough to change the trajectory of technology uptake (Niemeyer & Littleboy, 2006).

A key issue for the diffusion of technology into society is the manner in which it is perceived and the risks that are associated with it. When a technology is emerging the ideas are novel and unfamiliar, and they involve uncertainty in relation to levels of risk, depending on the information available. Research has shown that uncertainties and risks that will influence public perceptions about the acceptability of a technology, suggesting the issues that are of most concern to residential customers are those that will have a direct effect on their lives and those of their friends and families, including personal security and safety, financial security both now and in the future, and health and wellbeing (Slovic, 2000). Recent research in regards to smart meters show key concerns are around health and privacy, as well as the impact of pricing mechanisms such as time-of-use pricing on vulnerable households. This suggests it is important that if these technologies are to form part of the future electricity grid, reducing the uncertainty that surrounds these technologies will be paramount.

An important consideration is the strength of attitudes. Attitudes which are strongly felt are more likely to be stable and enduring and more likely to influence behaviour, whilst weak attitudes are more flexible and likely to be constructed on the spot and unlikely to have an effect on behaviour (Maio & Haddock, 2010). Attitude strength can be influenced by a range of factors including (but not limited to) the ability to recall the attitude from memory, whether or not a person has had direct experience with the issue/object, how important a person rates it in relation to other things, and whether or not a person has mixed feelings about it (Maio & Haddock, 2010). The research reviewed as part of this desktop study, indicates that the general public (outside of trial participants and communities subject to mandatory rollouts) have low knowledge and lack experience with many of the emerging electricity technologies, and as such their attitudes are not strongly formed and are most likely to be constructed on the spot. With electricity use being invisible to the residential customer to date, it has resulted in a lack of awareness, knowledge and incentive for customers to participate. In the case of smart meters and TOU, however when explained in detail, participants were more likely to develop more positive attitudes towards them. This suggests in addition to addressing the key concerns surrounding the technologies, engaging with customers' early, before attitudes are strongly formed, is crucial.

Trust is an important factor to both addressing key concerns and engaging customers. A lack of confidence in the ability of industry, government and science to manage the associated health, environmental and social risks of any technology is likely to compound any negative risk perceptions that they already hold (Slovic, 2000). Similarly, trust influences how information is interpreted and how well messages are received. If trust in the messenger exists, communication is relatively easy; if trust is lacking, the process is much more difficult (Slovic, 2000). Studies cited in this desktop study suggest that utilities generally do not currently garner much trust from customers. The research undertaken by Lineweber (2011) in the USA indicates there are gaps between what customers' value and what they believe they will receive in terms of benefits from smart meters and pricing mechanisms such as TOU. The study also found scepticism amongst customers about whether their key concerns will be addressed. This is an indication that building trust and respectful relationships between the residential customers, the electricity sector and government stakeholders, is going to be imperative for the electricity sector moving forward.

Evidence cited in this desktop study suggests that in addition to low knowledge of emerging electricity technologies, household knowledge of energy use is also low and particularly so in terms of which appliances contribute most to bills. The Australian Bureau of Statistics reports a high percentage (91%) of customers' who say they would be prepared to make changes or take actions to use less energy if they were given more information on how they could do this without compromising their lifestyle. A number of reports confirm this finding and suggest customers say they are interested in changing their behaviour but perhaps lack the knowledge to do so, which might explain why the trends still show continued use of energy intensive appliances.

There are also reports to show low income customers often have less awareness and knowledge about emerging electricity technologies than the general population. This suggests additional effort will be required to ensure these customers are provided with the necessary information, via the means they are most comfortable, to ensure they too are able to make informed decisions. An individual's socio-demographic profile is not an indicator of what they value. As an example, somebody with a low income can value the environment just as much as somebody with a high income and therefore just as likely to alter their behaviour to be in line with their values and beliefs as much as possible. Reports show vulnerable households do not perceive certain behaviour changes (i.e. to shift peak load) any more difficult than the general population. Such findings are applicable to the debate around the impact emerging electricity technologies, such as flexible pricing, has on vulnerable households and recent modelling suggests, given certain conditions, most residential customers can benefit from flexible pricing, including vulnerable households.

Not changing behaviours, despite best intentions, is however not limited to any particular socio-demographic profile. As outlined above, many residential customers say they want to reduce their energy bills but they continue to behave in ways that are contradictory to their intent (i.e. increase use of energy intensive appliances). Likewise, while many customers say they are willing to pay a price premium for 'green power', only a small number make the leap from interest to purchase/premium payment. While this may be partly attributable to knowledge, research suggests that motivations (i.e. to help the environment) do not necessarily translate into behaviour (i.e. turning off lights, installing solar panels); other factors come into play.

Behaviour can be influenced by a number of factors, including preconceptions about self and others, monetary factors, social influences (what peers and community members are saying and doing), and convenience. The Theory of Planned Behaviour suggests that an action will be performed if (a) the person's attitude is favourable (b) the social norm is also favourable (i.e. their family and friend's view is also favourable) and (c) the level of perceived behavioural control is high (i.e. the extent to which a person believes it is easy or difficult to perform an act (Vaughan & Hogg, 2002). In the example of 'green power', lack of strong social norms and personal relevance, inconvenience of switching, uncertainty about the quality of green electricity and lack of accurate information have been identified as barriers to uptake. 'Cost' is generally top of mind, with research showing residential customers want to save as much as possible, and are not willing to pay more than the expected value of return. Cost therefore acts as both a primary motivator and a key barrier for uptake. For example, higher electricity prices have been shown to encourage peak load reduction but the high price of an electric vehicle compared to the alternative is a current barrier to its widespread adoption.

While cost is most commonly the predominant factor, studies do suggest there are other complementary decision factors that customers consider, including reliability, quality, safety, control and environment. There are instances where these factors can be more influential than cost. As an example, early adopters of a technology often rate other features as more important than cost. Economic incentives are not always a motivator for the uptake of distributed generation technologies; features such as environment and control are more highly regarded. Likewise, it has been shown that early adopters of electric vehicles do so more for ideological reasons than any cost benefit. Technologies that appeal to early adopters and gain a strong following amongst these customers may struggle to find mass acceptance or take some time to transition from niche to mass-market appeal. Therefore, for widespread adoption of electricity technologies, it is likely cost will be an important factor.

Research specific to emerging electricity technologies shows information and feedback needs to be clear, accessible, appealing, relevant and timely. Key components of successful implementation programs included customer involvement through engagement, education, consumption feedback and supporting technology. One-way communication is now widely viewed as an ineffective method for achieving technology acceptance (e.g. Grove-White, Macnaughten, & Wynne, 2000) and may even lead to a hardening of pre-existing negative attitudes (Scholderer & Frewer, 2003). Rather than one-way information a system of two-way communication is required. Fischhoff (1995) illustrated the spectrum of possible approaches to risk communication through the following list, ordered from least to most effective:

- *All we have to do is get the numbers right*
- *All we have to do is tell them the numbers*
- *All we have to do is explain what we mean by the numbers*
- *All we have to do is show them that they've accepted similar risks in the past*
- *All we have to do is show them it's a good deal for them*
- *All we have to do is treat them nice*
- *All we have to do is make them partners*
- *All of the above. (Fischhoff, 1995, p. 138)*

Attitudes and knowledge do change over time, so for an accurate and up-to-date reflection of this perspective, it is important that engagement is continuous, not an isolated event. In the case of emerging electricity technologies, some reports have suggested that much focus has been solely on technology development, perhaps at the expense of due consideration of the needs of the customer. This desktop study has provided evidence towards the important influence the residential customer has on determining the trajectory of a technology. With the role of the customer likely to increase in the future, continued consideration of the social dimensions is therefore imperative.

4.1 Research gaps

The process of this desktop study has identified some gaps in the existing research which presents an opportunity for future research aiming to understand the social context of the electricity grid in Australia. In particular, it has highlighted the importance of research in this area becoming more strategic about understanding the social context of the electricity sector and extending beyond market research. Some opportunities for future research in this area include:

- Understanding perspectives on other emerging technologies outside the household level i.e. community energy; high voltage lines.
- Acquiring accurate representations of attitudes and knowledge by utilising mixed method approaches – i.e. qualitative and quantitative.
- Observing and understanding actual behaviour (e.g. apply a social practices approach) rather than self-reported behaviour.
- Understanding the role of trust
    - Does information from multiple sources increase trust?
    - Is 'procedural fairness' a factor that determines trust?
- Exploring message framing and its affect on attitudes.
- Exploring the role of perceived 'equity'.
- Testing the effect of social norms.
- Understanding the role of incentives/compensation (including non-financial incentives).

5 Conclusion

This report provides an evidence base to contribute a social dimension to the Future Grid Forum when considering the range of current and potential issues and opportunities facing the electricity system and proposed response strategies. The review has explored the impact of knowledge and attitudes towards emerging electricity technologies to determine their overall acceptability from a residential customers' perspective. It has drawn on theories from psychology and social science to present insights into which features a residential customer is likely to accept, those that may require strategies for improved adoption, and those that may require modification. Results from the range of research studies reviewed have highlighted a number of key issues relevant to the residential customer and the future of Australia's electricity grid and answer a number of questions that were of particular interest to the Future Grid Forum.

Most residential customers have low knowledge (and experience) of many of the emerging electricity technologies and of their energy use, particularly the contribution of appliances to electricity consumption costs. As well, in many cases, attitudes of residential customers are not yet strongly formed about many emerging electricity technologies. This presents an opportunity for early engagement to help build trusting and respectful relationships between the residential customers, the electricity sector and government stakeholders. Engagement should be ongoing (rather than a one-off) and involve two-way communication. Research suggests additional effort will be required to ensure vulnerable customers are provided with the necessary information to ensure they too are able to make informed decisions and to ensure the uncertainty that surrounds emerging electricity technologies (i.e. privacy, health and impact on vulnerable households) is reduced. How attitudes and knowledge are acknowledged and addressed today (or not) will influence the uptake trajectory of the technology into the future.

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